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CONCERNING FOUNDATIONS FOR HEAVY BUILDINGS IN NEW YORK CITY.

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WITH DISCUSSION.

As an introduction to what follows, it would seem well to describe briefly the chief conditions met under the surface in the parts of New York City where the high buildings recently constructed and proposed are situated. To this end a map of the city below Twenty-third Street is given in Fig. 1, which shows the principal topographical features of that territory before it was built upon. The dotted portions near the shore line show the made land, which it will be noticed is generally from one to two blocks in width. This map shows that Broad Street to above Exchange Place and Maiden Lane to Nassau Street occupy what were formerly inlets from the East River, and that there were ponds east and north of City Hall Square. There seems to have been a natural waterway practically all the way from the North River following about the line of Canal Street and into Collect Pond, and from thence to the East River near Chambers Street. Notice should be taken also of the location of Minetta Stream, which was formed

near the present junction of Eleventh Street and Sixth Avenue. This stream flowed through what is now Washington Square and into the Hudson a little below Houston Street. The lines indicating elevations must not be allowed to mislead; in many cases the comparatively elevated portions are land made by the processes of Nature in comparatively recent times, it being rather the exception in the lower part of the island to find other than a drifted or deposited material within the distance below the surface at which the foundations of buildings are usually built. This upper material is mud, silt, sand, usually from fine to very fine, and sometimes gravel. The hard stratum below it, where not rock, is generally an exceedingly firm and compact surface of silt, clay and gravel containing stones of various sizes, which is generally called hard-pan. This is so hard that, in reports on the borings taken to ascertain the nature of the underground material about the city, it has generally been referred to as rock. The so-called bed-rock in the profile prepared for the proposed rapid transit tunnel road is this material, in all probability, in lower Broadway. In its natural condition in place it is so hard that for all the weights that can come on it through the construction of buildings it may be considered absolutely unyielding. It cannot be dug up except by pick or chisel, and in large excavations can be best loosened by blasting. It may be well to state here that in the case of the Manhattan Life Insurance Building, the weight of which is borne on fifteen caissons proportioned to carry a pressure at their bases of 10.8 tons per square foot, some of them rest on solid rock and some on the compact stratum mentioned, and that not the slightest settlement can be discovered. As to its safe bearing capacity, there can be no question but that it is well in excess of what under the present building law may be put upon it by means of a concrete base, 150 lbs. per square inch or 10.8 tons per square foot.

As the thoughtful engineer views the building methods prevailing to-day, it would seem to him that there is perhaps no kind of construction where the force of habit has so disastrously hampered a proper and quick readjustment to new conditions. Buildings of the heights usual until recently seldom put upon the earth supporting them weights greater than 3 or 4 tons per square foot, and generally much less than this. The weights were distributed and spread without difficulty by the common methods that had always been used. Of

course there was occasionally some particular case sometimes treated in an exceptional manner, but these were never important or numerous enough to bring about any radical change, either in the general carelessness with which the matter of foundations of buildings was considered,

FIG. 1.

or rather not considered, or in the method of constructing them. Nor was this necessary, because the earth held reasonably well the buildings built upon it, and, too, the cost and probable life of the buildings did not warrant a greater expenditure upon the foundations. The

weight upon the soil did not compress it to such a degree as to cause serious settlement, nor did it put the material under a pressure which would press it outward or upward if given an opportunity by a near-by excavation. With the sudden doubling of the usual height of buildings, and the consequent great increase of weight, the old foundation methods became, in many cases, entirely inadequate. If pursued, serious settlement was invited from overloading, and the danger of letting down the underlying material by lateral flow became considerable. In fact, the problem of foundations for a heavy building, where they are not carried to rock or hard-pan, has now become (and this fact seems to be strangely overlooked) one very largely of what vent may be given for the underlying material by excavations in the vicinity. It is not sufficient that the weight put upon the soil should not be so great as to cause serious settlement. Under the conditions existing this is not generally difficult, but the material must not be put under a pressure that will cause it to squeeze out from below in case an opportunity is afforded by deep excavations nearby. It will become apparent ere long that the erection of heavy buildings resting upon sand or soil, which they unduly overload, without carrying their foundations on piles or to solid material, has in many cases worked a serious wrong to owners of the adjoining lots, besides being itself a short-sighted economy, because of trouble and lessened value of the buildings so built. For instance, the author knows of one building of great weight, a very excellent and costly structure with a carefully built foundation, which, however, rests simply upon the fine sand into which it has settled slightly. This settlement, as was anticipated, has been uniform and has caused no damage, but the owners are aware of the danger of serious or disastrous settlement that may take place from the operations of putting in foundations of buildings in the neighborhood, even though at a considerable distance from them, for at no great depth below their footings there is material, if it be like that revealed by the nearby operations, which would be likely to squeeze out under the existing pressure, if given a vent, especially if at the same time there is any exciting cause from jarring or pumping. The shoring and underpinning of such a building, while possible, would be vastly more difficult and costly than for a building of but a few stories' height. It would, for instance, cost probably more than $100 000 to care properly for the building in question when the property adjoin-

ing is built upon, unless the height of the new building were kept considerably below what would now be the height of the most suitable improvement of the property. Under the present building law, when a structure is built alongside another and this latter has its foundations not less than 10 ft. below the street surface, the responsibility and cost of caring for the old building must be borne by the owners of the new adjoining one. Thus in the case just cited, when the property alongside the building mentioned is adequately improved, the builders have to grapple with the problem of supporting and probably building a new foundation under this building. Thus the fact that this building, while conforming to the building laws, has put the soil beneath it under unusually great pressure, will cost the owners of the adjoining lots at least $100 000, beside any damage that they may cause the old building. The question very forcibly presents itself, whether in the absence of specific statutes on the subject, the common law cannot and should not be invoked to prevent any owner from putting the soil beneath a new building under such unusual pressure that it is under a dangerous tendency to squeeze laterally and thus materially limit his neighbor's future improvement, or else put him under great additional expense in carrying it out. In equity he should certainly be required so to use his own lot as not to injure that of his neighbor. It will be strange if this matter does not soon come up for consideration.

Where soils are overloaded there is extraordinary potency in slight vibration to cause settlement where the conditions are favorable. Hoisting engines are frequently found to be exciting causes in producing unequal settlement in the absence of unequal loading. In one case in lower New York where a very massive and well-built structure resting upon gravel and sand cracked after it had been in use a considerable time, the only new condition introduced to which it seemed possible to attribute the settlement manifested was pumping clear water from a nearby driven well. It seemed reasonable to assume that the water flowing through the sand made possible a slight readjustment of the particles which settled into closer union under the vibration of the machinery in the building.

A most interesting thing often shown by the settlement of buildings is the frequency of movement of the entire mass of soft material in the vicinity of rivers. There is a locality in New York City where there is

good reason to believe such a motion to be taking place. For instance, a certain large and well constructed building resting upon a well designed pile foundation, and where the piles were driven 40 or 50 ft. into the silt, started to settle, probably before it was completed; at any rate, it settled from almost nothing at the end farthest from the river to some 2 ft. at the end nearest the river, making a practical wreck of part of the structure. This building was some 200 or 300 ft. from the river. An examination of the bulkhead wall showed that the piers had apparently acted as buttresses to hold it back, but that between the piers it was bowed outward. This, in connection with other evidence, seemed to point indisputably to a movement of the entire mass of the adjacent material toward the river, occasioned by the weight of filled material and buildings, and it seemed probable that this movement was shared by the silt to a considerable depth below the filling.

The first method that naturally comes to mind for providing a better foundation than can be done by simply spreading the bearings on the earth at customary depths is that of driving piles, and where there is reasonable certainty that these will always remain wholly submerged, this is generally the best possible foundation, considering its cost, for buildings of considerable but not of the greatest weight. The New York building law permits a load of 20 tons per pile, and engineers will consider this, when fair-size piles are used, to be within good practice; but there are many cases where it is certainly a great mistake to take the aggregate bearing capacity of a pile foundation to be the sum of the safe loads on the individual piles composing it. The sustaining power of a single pile may be said to be practically the sum of the friction which holds it on the sides, and the resistance to penetration at its lower end. It is obvious that in very many cases where a large number of piles are driven close to one another, the piles simply replace so much material which has been displaced to make room for them. It is true that the material remaining about them may by the process of driving become so much more compact that it increases the friction and perhaps the resistance to penetration at the lower ends of the piles; but if the stratum below the piles be at all yielding it is probably true that the bearing capacity of the foundation is the bearing capacity of the stratum below the piles plus the friction of what might be considered the outer side surfaces of the entire mass penetrated by the piles. In other words, the piles merely

replace so much yielding material and transfer the load to the stratum beneath them.

A practical difficulty which is apt to hamper the construction of a good pile foundation for a building very seriously where there are a great number of piles close together is that, after driving the first few, the material near them becomes so compact that it is exceedingly difficult and sometimes impracticable to get the remaining piles down to anything like the contemplated depth. It may be comparatively easy to drive the first one, say 30 ft., and may become exceedingly difficult to drive those put down later to a depth of more than 10 or 15 ft. This difficulty is readily overcome where the use of the jet may be resorted to. This is often dangerous in proximity to other buildings, and, too, it sometimes seriously cracks the adjoining building to drive piles close to it.

With regard to the piles remaining permanently submerged, there have been some rather startling experiences in New York City. There is one building, the value of which is probably in the neighborhood of $1 000 000, built upon piles, the upper ends of which it was found before the completion of the building would be shortly exposed, and it is said that it was decided to enclose the entire foundation in a dam, so to speak, in which the water is kept by pumping at a safe height to cover the piles. One of the leading builders in New York a short time ago removed a building which rested on piles driven but a dozen years ago, and he found them seriously decayed. Throughout the gravel and sand deposits of the lower part of New York there is an abundance of fresh water, which rises and falls to a greater or less extent with the pressure of tide water upon it. The supply from springs must be very great, because there are a vast number of driven wells throughout the region, supplying water for steam and other purposes. The water level at any one point may be materially lowered at any time by pumping from a driven well in the vicinity or from the constant drainage of some leaking basement or other excavation. Thus it would seem that the permanence of any given water level in the city can rarely be relied upon.

In considering the provision of an adequate foundation for a building, the weight of which seems to require something better than the old style of simple foundations, the first natural thought is to increase in some way the spread of the foundation so that the unit weight on the material may be kept within allowable limits. In Chicago, where

the material on which the city is built consists generally of a thickness of 40 to 100 ft. of blue clay of more or less yielding character which can scarcely be loaded safely 2 tons per square foot, the general practice has come to be that of proportioning the area of the column foundations in a uniform ratio to the column loads upon them, in order to get equal settlement under all the columns. This has resulted in the so-called raft system of foundations, in which, by alternate layers of steel beams of lessening length, it is practicable to spread the bearing to a sufficient extent. This method requires the minimum depth of excavation and gives the minimum amount of cellar space. Short of some method of carrying the bearings to a lower and more substantial stratum, as by piles or by excavation to bed-rock, this would seem to be the best possible treatment of the problem under such conditions as exist at Chicago. That this method should be at all satisfactory requires a comparatively uniform condition of material under the entire building, uniform in character, in compressibility, in softness and in depth.

This raft method has been employed in some cases in New York. For buildings in the lower part of the city it is open to the objection that the conditions under the entire building are not apt to be uniform, and there is often the very serious objection that at some part, if not under the entire building, the material at some depth may be sandy, or of the nature of quicksand, and may yield or be relieved at some future time. Of course, there is always the question as to the durability of steel beams, even though encased in concrete, where they are below the water level.

In considering the loads to be provided for by the foundations for the Manhattan Life Building it was found that if piles were driven over the entire space to be covered by the building, enough piles could not be driven on the lot to sustain the building and load the piles within the limit permitted by the building law. Thus, unless the simple method of spreading the foundations was considered satisfactory, which in this case was out of the question, there was no way but to carry the column loads from the bed-rock, which was here 54 ft. below the Broadway street level. The borings taken on the lot indicated the existence of more or less quicksand, and it was feared that any effort to excavate for foundations in the open to the bed-rock would result in an inflow of material that would endanger the adjoining build-

ings. For this and other reasons, the architects, Messrs. Kimball and Thompson, decided upon the use of steel caissons sunk by the pneumatic process, and thus came about the first use of this method.

Its advantages are: First, the excavation can be carried on under pressure, which holds back from inflow any outside material; second, any obstructions met with in the sinking can be removed without serious difficulty or delay; third, the bottom can be examined, and, where necessary, leveled or stepped; fourth, the work can be executed with speed, because the caissons can be brought on the lot finished or ready to put together, and while these are being sunk the brickwork to form the permanent pier can be built upon them, so that when the excavation for each foundation is completed, the pier itself is finished. This method has been employed in obtaining foundations for the American Surety Building and for the new Standard Oil Building, and its use is contemplated in other buildings soon to be erected. It would not seem worth while to deal in detail with the construction and sinking of the caissons, because the general method is familiar through its application to bridge foundations. Some points, however, should be mentioned. In these comparatively small caissons with vertical sides, sunk the entire distance through earth, the friction is in much greater proportion than occurs in bridgework. As soon as the brickwork, built as high as is practicable, proves of insufficient weight to make the caisson follow the excavation against the upward pressure of the air and the friction, it becomes necessary to put on a temporary load. This is done by piling on pigs of iron. Another respect in which this work differs from bridgework is the fact that excavations in the material should preferably be carried on by means of a Moran or other lock without permitting reduction of the air pressure.

Of course when the depth to hard bottom is not great and there is no running material over it, the excavation may be made in the open air under the protection of sheet piling, and this is in such cases the simplest and cheapest means of doing the work.

The foundations for the new Johnston building have been successfully put in by means of open wrought-iron cylinders sunk by the water-jet process. This method, while somewhat cheaper than the pneumatic, would seem to be open to the objection that it might not permit in some cases a proper examination and preparation of the bottom and of building the foundation in the dry, and, too, should flowing material under

heavy pressure from beneath an adjacent building be encountered, a possibly dangerous vent might be afforded. As yet the pneumatic process is the one safe and sure method for deep excavations, by which all dangers of quicksand or other difficulties can, with certainty, be quickly overcome and a perfect foundation constructed, and this, too, at a cost, where the conditions are determined, which can generally be estimated with comparative certainty.

While the necessity of better practice than has heretofore obtained in building foundations for heavy buildings is happily becoming somewhat more apparent, it is hard to understand the general lack of solicitude on this point on the part of those constructing new buildings. They are generally content to let the judgment of their architect govern, who probably has never before had such a problem to solve. Having engaged him they fail to see the necessity of employing in addition an engineer expert in foundations, and yet the writer ventures to say that in most cases, aside from the other advantages, his fee would be more than saved by the economy resulting from his guidance. It is probable that a sum not exceeding 3 or 4% of the cost of the entire building, added to what the cheapest possible shallow foundation would cost for one of the very high buildings, would cover the extra cost of carrying its foundations to the solid rock, when this is within 70 or 80 ft. of the surface. In many cases this extra cost would be more than offset by the value of the additional story or stories that could be provided beneath the surface.

When an owner has once realized the importance of getting his foundations on the rock he generally approaches the business treatment of the matter in a very narrow-minded and stupid manner. With a distrust born of the imposition of conscienceless contractors, he wants to be certain that his foundations will be completed for a given fixed sum, and this in advance of the determination of the various depths, corrected weights, dimensions and so forth, which is obviously impossible without injustice either to him or his contractor. The proper way for this work to be done is for the owner to engage a party whose integrity and capacity he can trust to do the work for him, for its net actual cost plus a fee as compensation or profit. Such an arrangement brings all interests into unison, permits much preparatory work to be done before the work could be let by contract, and gives the work finally to the owner at what, and only what, should be paid for

it. It results in the best work carried out in the quickest time, with freedom to improve plans as the work progresses, and with the pleasantest relations of owner, architect and foundation builder.

The author wishes to apologize for the absence of detail in this paper; it was intended to present only general considerations. The time would seem ripe for discussion of the matter of foundations of buildings. It should be brought to the minds of architects and property-owners that soils, like metals and woods, have limits of strength and cannot be overloaded without inviting trouble. If there is an absence of that principle to do things well, which should be an instinct with all who build, they must be shown the false economy of their inadequate methods.

This general consideration of the subject treated has been offered in the hope that it will call forth valuable discussion, and that its author is not mistaken in assuming the Society to be the center from which such good influences as are needed must emanate.

DISCUSSION.

Mr. Hains. PETER C. HAINS, M. Am. Soc. C. E.—The paper refers to foundations of heavy buildings in New York City, but as pile foundations are not uncommon there, and as it is generally believed that piles cut off below the level of standing water are safe from decay, it may not be irrelevant to call the attention of the Society to one case where this rule has not apparently held true.

Between the years 1833 and 1849 several thousand piles were driven for the foundation of old Fort Delaware on Peapatch Island in Delaware River. These piles were cut off about 20 ins. below the level of mean low tide, the mean rise and fall of which is about 5 ft. It is proper to remark, however, that the level of standing water within the enclosure of the fort, while it varies somewhat with the tides, does not vary to the same extent, so that the lowest level of standing water where the piles were driven is above that of mean low tide outside. In other words, the piles were cut off considerably more than 20 ins. below the level of standing water, and there is not the slightest doubt but that the level of standing water has never yet been below the tops of the piles, yet some of these piles decayed to such an extent near their tops that a stick could be pushed through the decayed part several inches.

Several were broken off by the comparatively slight strain brought on them by attaching a guy reaching to the top of a pile-driver frame

Mr. Hains. to steady the latter. The decay was apparently confined to the upper 4 or 5 ft. of the pile, at least that was found to be the case with one that was pulled out, and was apparently the case with all that were examined. The decay was mostly confined to the sappy part of the stick; the heart was scarcely affected, and grillage timbers that rested on the heads of the piles were found to be sound. The decayed part was greatest at the top and gradually decreased downward until at 4 or 5 ft. below the top the decay disappeared.

The piles were of rather poor quality Chesapeake Bay pine from 12 to 14 ins. in diameter, and many of them had apparently been injured by hard driving. The rings of annular growth in some cases showed no cohesion whatever. One pile was pulled out and found to be 27 ft. long, well preserved from the point to about 5 ft. below the top. Another stood a pull of 60 000 lbs., and two broke off, with a less pull, where the chain was attached.

The soil into which they were driven consists of a soft, bluish black mud to a depth of about 42 to 45 ft. From that depth to 85 ft. various strata of sand are found, some fine, some coarse. The sand strata contain plenty of water, the level of the latter rising in the well above the level of mean low tide. Below 85 ft. there is said to be compact clay with boulders. The upper strata of mud has a disagreeable odor with indications of marsh gas. The piles had to carry a safe load of about 30 000 lbs. per pile, if the load was evenly distributed. Between the years 1859, when the fort was finished, and 1866, the fort had settled as much as 4 ins.

This experience indicates that it is not always safe to assume that pile foundations for buildings will remain free from decay even if the timber is below the level of standing water.

Mr. Berg W. G. BERG, M. Am. Soc. C. E.—Many of the principles and methods of construction described by the author with reference to foundations of buildings can be employed very advantageously for general engineering work. Attention should be directed to the desirability of the more general use of iron and concrete grillage foundations for bridge piers and trestle bents located between the running tracks of railways or adjoining some other structure where a deep and large foundation pit would be objectionable. In making comparative designs between the iron grillage foundation and the general method of spreading foundations by means of masonry and concrete offsets, it is surprising to note in many cases, especially where heavy concentrated loads have to be provided for, the decrease in the size of the bed, the depth and the total weight of the foundation. The probable reason that the iron grillage system has not been used more extensively outside of foundations of buildings can be traced to the uncertainty existing in the minds of a great many engineers as to the durability of iron imbedded in concrete. The author admits that there is a question in this respect when the

iron is placed below the water level. In order to make the system more popular and to allow the use of iron in foundation work to be classed as good practice, it will be necessary to prove conclusively to the satisfaction of the most critical members of the profession that iron or steel will not deteriorate in contact with concrete. Mr. Berg.

CHARLES MACDONALD, M. Am. Soc. C. E.—The speaker was of the opinion that the high-water mark was the lowest level that any property owner might be expected to go with his foundations, and that from 3 to 4 tons per square foot, distributed properly over the New York sand at that level, is certain to give good results. There might be a settlement of a small fraction of an inch, such as has occurred in some of the largest buildings in the lower part of the city, which have been founded upon a concrete grillage or on piles; but why it should be considered necessary to change the practice of years to enable any individual to go down to rock for his foundation is a matter that would seem to be beyond the professional point of view altogether; it is a question of economics. If the owner of property believes he can utilize the space from the rock to the sky, at a price which will remunerate him for the expenditure, that is a question of business policy and not of engineering. It is admitted that the author of the paper is well equipped to put in foundations to the rock by the pneumatic process; but the expediency of resorting to the increased expenditure involved in so doing should not be decided upon engineering grounds alone. Mr. Macdonald

GEORGE B. POST, Esq.—For many years there was no decision of the courts on the embarrassing connection between 10 ft. depth of foundations and the liability of owners of property. It was not decided legally until recently whether there was a liability on the part of the owner using due diligence and ordinary care in erecting his building for the settlement of an adjoining building, which was due either to the compression of the soil adjacent to his foundation or to the friction of the walls of the two structures. A few years ago, a decision of the Court of Appeals was made to the effect that every lot has an inherent right of support in the adjoining soil, and if that support is impaired, damages must be paid for doing so. Under this law, in one case where the greatest care had been taken in a building to prevent settlement, this nevertheless occurred, and after a long litigation the party who was carrying on the work paid the cost of repairing the adjoining building. Mr. Post.

In a large district near Broad Street there is a true quicksand which moves with great velocity. The speaker once had a large sheet-piled test pit 8 ft. square dug 30 ft. south of the building of Drexel, Morgan & Company, and 80 ft. east of Broad Street. When the pit had been sunk through the overlying material, the man digging it nearly went out of sight in the quicksand, which squeezed out of the hole with

Mr. Post. great rapidity. Fortunately there was a large amount of concrete being made in the neighborhood, and by ramming this into the hole for twelve hours, the movement of the quicksand was stopped. Meanwhile lintels in buildings 200 or 300 ft. distance were reported to have cracked. This is not the character of the soil over the greater part of the city.

Near the corner of Broadway and Ann Street, where the speaker was erecting a high building, there are many lofty structures. The New York Post Office, a heavy granite building, is directly opposite, the Mail and Express and the Vanderbilt Buildings, Temple Court, the Potter, Times, World and Tribune Buildings all stand on sand, to which they transfer a pressure of over 4 tons to the square foot without causing any serious settlement. In the case of the World Building the blank wall on the east side imposes a pressure of 4.7 tons on the soil, and the foundation is loaded eccentrically.

While the speaker was not a great admirer of steel in concrete, the evidence of the last few years seemed to him to prove forcibly that where iron or steel is in direct contact with masonry it is thoroughly protected from corrosion. In pulling down the first Herald Building, which was over 30 years old, he directed the inspector to bring him the worst corroded pieces of iron he could find in the building. There were no bad examples found, and, where the mortar had been in absolute contact with the paint, the paint itself was preserved. All the reliable evidence obtainable goes to prove that cement mortar has the faculty of preserving iron and steel to a great extent from corrosion, and certainly of preserving from injury the paint which it covers. Another point to be considered in determining the relative advantages of the caisson and grillage foundations is that where caissons are used it is generally necessary to carry the weight of the building to them by means of cantilevers or grillages, and it is hard to see how the beams embedded in the concrete of a regular grillage foundation are in any more danger than such cantilevers and small grillages superimposed on the caissons at about the same level under ordinary circumstances.

It must be remembered that good architecture is always good engineering. The reason a well proportioned stone column eight diameters high is graceful is largely because this is about the limit such a column can be proportioned to bear its load properly. Good architecture and construction go hand in hand; where the engineering is bad, the architecture is generally bad, and where the architecture is bad, the engineering is usually worse.

Mr. Cooper. THEODORE COOPER, M. Am. Soc. C. E.—This paper, from one so capable of presenting facts and principles from his experience which would be of value and interest to every member of the engineering profession, is an unsatisfactory one. It speaks vaguely of "overloading

soils," "great pressures" and "danger of lateral flow," but gives no facts or opinions as to the conditions of loading which would cause lateral flow or produce undue loading. It leaves the reader to infer that the only safe or satisfactory foundations for buildings in New York are those on rock. While there are places where important buildings should be carried to the rock, the speaker did not believe it necessary or possible to go to rock in the great majority of cases in that portion of the city lying below Twenty-third Street. It would be a useless expenditure of money. If a material can be found with sufficient bearing capacity to carry safely the weight of the structure, it would be useless to go deeper than is necessary. Mr. Cooper.

In a general way there are four classes of materials within the business district of the city, upon which buildings must be founded. Along the North River front the material is largely silt, which has been sounded in places to a depth of 200 ft. without reaching rock. The dock walls are floated upon this material in a satisfactory manner.

For two and more blocks back from the river there is made ground partially floating upon the silt. Along the old water-courses and over the former ponds and marshes, where the underlying material is silt or soft mud, there is also made ground. The most difficult foundations in New York City are on this made ground. The maximum bearing capacity of such material depends almost entirely upon the floating capacity of the soft silt or mud immediately below the filled material, for in many cases piles cannot be driven through the filled material far enough into the lower and stiffer silt to increase its bearing power. Moreover, the conditions may be changed by the loadings on the neighboring ground. One of the examples of defective foundations named by the author was on ground of this kind, and the failure was due to the filling in of adjacent ground.

Rock can be obtained for foundations over a small area in the neighborhood of Bowling Green, at depths not exceeding 35 ft. Two miles farther up Broadway, about Fourth Street, rock can be reached at about 40 ft. below the street grade; north of this point the rock generally approaches the surface and occasionally crops out above the surface; there are, however, at places deep depressions in the irregularly underlying rock which are filled with mud, sand, clay or artificial filling.

Between Fourth Street and Broadway and Bowling Green, with the exception of the Canal Street district, the backbone of the island for a distance of about 2 miles is sand, varying from coarse building sand to sand of the finest kind. This sand is from 40 to 160 ft. in depth. It is over this district that the principal high buildings have been built and where the important question as to the necessity of going to rock for secure foundations must be considered.

Mr. Cooper. The illustrations of faulty foundations given by the author would have been of general interest if the full facts had been given, but they have no bearing upon the main question, viz.: Can high and heavy buildings be founded securely upon the sand which underlies the principal business district of New York, or should all buildings of this kind go to the rock below, regardless of cost and other conditions?

The answer to this question must largely hinge upon the bearing capacity of this sand and its liability to be effected by future conditions. The author acknowledges that "until recently" buildings in New York seldom put upon the earth supporting them greater loads per square foot than 3 to 4 tons, and the earth held such buildings reasonably well. Plenty of buildings 10 to 12 stories in height have been well supported with loads of 4 tons, and in some cases as high as 5 tons; if these buildings were well supported under these pressures, when using a small portion of their ground area, why cannot higher buildings be equally well sustained by using the same units over a greater area of their base? Buildings 25 stories in height can be built without exceeding 4 tons upon their full base. There are a number of high buildings which rest upon this sand and have for several years without any signs of difficulty. Tests have been made which show that this sand, even of the finest kind, can sustain at the level of high water loads of 6½ tons per square foot under vibratory action without showing the least evidence of movement after the first small initial settlement, and it is possible that even higher loads could be put upon it under such conditions without movement. The building law allows 4 tons; there has been no evidence produced to show that such loading is not safe and reliable. Proof to the contrary must be advanced before question can properly be made in regard to the reliability of such loadings.

That sand is not a reliable material for foundations, when it is possible to have it removed by the action of running water, from the flow of streams, springs or surface drainage, or when it is so quick under saturation as to be forced out by the pressure, is not disputed. Failures of foundations have occurred from this action, but generally the sand in the district under consideration does not flow readily even under pressures as high as 6½ tons. The mean high-water level, which may be considered as the permanent water line, owing to the sluggishness of flow through this fine sand, is about 20 to 40 ft. below the street grade. High buildings need all of this space for cellars and basements for machinery and storage purposes. It can be assumed then that the foundations of high buildings will go as low as this mean high-water line. At this depth there is no flowing water from surface drainage, springs or tidal flow. The only other natural cause affecting the stability of the sand is the flow due to the pressure of the load; therefore, in all general cases, foundations at this depth can be con-

sidered secure under pressures not exceeding the usual practice of 4 tons, unless they are injured by being undermined by the excavations of some more ambitious neighbor. Mr. Cooper.

This leads to the second branch of the paper, viz., that duty to neighbors requires high buildings to be carried to rock, regardless of expense. The existing law and practice for many years in this city has been to require in new excavations that all previous structures founded 10 ft. or more below the street grade should be protected and maintained by the parties making the excavations. For the earlier buildings of few stories 10 ft. was a sufficient depth, and as buildings increased in height the depths have been increased, but no change has been made in the law. It is questionable if a greater legal depth would be in the line of public policy, for it would tend to put persons of moderate means at the mercy of their wealthier and more grasping neighbors.

If the author intends to suggest the change only for high buildings, it is unnecessary, for self interest will compel the owners to go as deep as the high-water line. If any owner desire to go lower, he should do so at his own expense and risk. No new law can effect existing rights under the present law. If any law is to be enacted in reference to high building, such law, in the speaker's opinion, should restrict the height of any building by an equitable consideration of other people's rights, or far below the heights already used.

The author mentioned a building where the pile foundations have been surrounded by a dam and a pump used to maintain the water level about them. As this is a special case, though having no bearing upon the question of suitable foundations, the speaker gave fuller facts in regard to it. This building, supposed to be a first-class structure, was closed out under a mortgage. The new owners found themselves in possession of a pretentious structure requiring very large expenditures to be put in rentable shape. The building was very extensively rebuilt, and desiring to limit the expenditures to a minimum until the rentable value of the building could be determined, the owners accepted, under advice, this method of protecting the piles. In connection with some advisory work on the superstructure, the speaker was incidentally asked in regard to this method of protection and unhesitatingly condemned it; he then learned that it had already been completed.

C. T. Purdy, M. Am. Soc. C. E.—If caissons can be afforded and the money can be spent to support a building on rock by their means, there will probably be no trouble with the settling of the structure afterward, but in Chicago, where the speaker had been engaged chiefly, the cost of caissons prohibited their use absolutely. Chicago foundations settle, some of them an inch or two, and some of them much more. There are a number of old buildings in Chicago which Mr. Purdy.

Mr. Purdy. have been wrecked because of unequal settlement. The old post office is an example, which was built on a bed of concrete spread over the entire area of the lot without any effort to proportion the bearing area of the concrete to the loads. The same unequal settlement compelled the Board of Trade to take the top off the tower of its building, and mar what was the pride and landmark of Chicago citizens. Hence, in constructing new buildings it was recognized that the problem was to make them so they would settle uniformly, and not to prevent any settlement whatever. It has been demonstrated that if loads are calculated and distributed properly, and the bearing areas of the foundations proportioned to correspond with the weights coming on them, so they will balance about their centers of gravity, the buildings will settle uniformly. It is impossible to predict how much the settlement will be, as the data on the subject point to no uniform law or laws in this respect. The settlement in itself is not a cause of injury to the structure, as is shown by a building in Chicago which has sunk 10 ins. without causing a crack in the plaster.

Where grillage foundations are adapted to the conditions of a structure and can be built more cheaply than other types, there is no good reason why they should not be used. Adjoining walls can be cared for, as is done all the time in Chicago. It is an easy and not expensive matter to put such a wall on pins and keep it there until the building has settled, which generally takes but a few months, and the work is not so expensive as going down through 80 ft. of soft clay to solid rock.

William Sooysmith, M. Am. Soc. C. E., has objected to the grillage foundation and uses in place of it a combination of open caissons and piles. It has proved a very difficult matter to put in such foundations without disturbing the surrounding property. The water-jet cannot be used in the soft clay underlying Chicago, and it is a difficult task to push an open caisson through this material, on account of its tenacity and the great friction between it and the skin of the caisson. E. C. Shankland, M. Am. Soc. C. E., has recently tried driving short piles under the grillage and this may prove quite successful.

Steel bedded in concrete has not been used long enough to warrant a judgment as to its durability, but iron has remained in concrete for twelve or fifteen years without injury. It is also to be noticed that after a careful study of American and European construction of this type, it has been decided to build the subways of Boston of steel-concrete construction, the beams to be painted with a mixture of cement and water before being laid in the concrete.

CORRESPONDENCE.

F. COLLINGWOOD, M. Am. Soc. C. E.—With the advent of the enormous buildings now being introduced in all large cities, the methods of founding as well as of building must be readjusted to meet the new conditions in both economy and safety of construction. Experience shows that the materials composing the substrata on Manhattan Island are very heterogeneous in character, and while with the moderate loads imposed by the older style of buildings there was but little unequal settlement, under loads of anything like 10 tons per square foot, the settlement will be so great as to become dangerous. In many places the underlying rock is very uneven, and the tendency to lateral movement and splitting of walls is consequently very great. It is manifest that under such conditions the ordinary rule of a definite increase in width of footings for each story of increase in height is not satisfactory or safe; and yet it is still considered all sufficient by most mechanics, because it is so provided in the building laws. Mr. Collingwood.

In sinking the New York caisson of the New York and Brooklyn Bridge, 20 ft. of a very fine running sand was passed through, which did not appear at all beyond a diameter of about 50 ft. In a distance of some 80 ft. the surface of the rock dropped 18 ft. In other parts of the island the declivities in the rock surface are much greater.

The old method of sounding with a crow-bar after excavating to the specified depth must clearly give way to more scientific methods, and no foundation be constructed without an accurate knowledge of the conformation of the underlying rock. From the writer's experience with the water-jet he is inclined to endorse the opinion expressed in the paper, that the pneumatic system is the safer method of founding in all cases where there is fine material liable to run. It has the further advantage of enabling building to be done in the dry in all cases.

GEORGE HILL, M. Am. Soc. C. E.—The paper is disappointing, because it treats in a general way of a subject which is a special one to a very unusual degree, and demands for its proper solution numerous specific examples as to cost of execution and time required for it, in order to enable the consulting engineer or architect to arrive at an approximately correct solution. For five years past the writer has been of the opinion that for the general case, some form of spread foundation was all that was required for the support of a properly designed building. When the first experiments were under way with the pneumatic foundations, he expressed the opinion that they were objectionable on the score of excessive consumption of both time and money without real compensating advantages, and judging as an outsider from the reported prices paid for the execution of the work, the months required for its execution, and the damage done to adjoining Mr. Hill.

Mr. Hill buildings, there has been no reason for a change of view. The cost of execution of the work, the causes for what appear to be interminable delays, the period when the walls of adjoining building cracked by settlement, are all factors which might modify the judgment were they correctly stated, and consequently a statement by the author as to what he had done and the cost of doing it, and the various circumstances attendant thereon, would have been of great value.

A building is erected to serve almost any conceivable purpose other than solely to show the engineering skill of its designer. As a consequence it must have among other elements, and as the most important of them: first, a good artistic effect; second, a minimum of cost; third, a maximum of area available for useful purposes; fourth, a minimum of material; fifth, a minimum of time required for its erection, and sixth, maximum desirability.

These limitations demand therefore for every large building, the complete and skilful use of the skeleton method of construction, by which is meant a steel skeleton secured against all vertical and horizontal forces, to which it may be subjected; encased in a fire-proof covering of ornamental character, the deep reveals being secured by turning the walls in at the windows rather than by thickening them, and the absolute elimination of all self-sustaining walls. The requirements of lighting limit the effective width of base, and consequently the height to which it is possible to carry the building, and brace it properly against wind pressures. Unbraced buildings carried excessively high will, within a relatively few years after they are completed, sway so under wind gusts as to alarm their tenants. The cost of putting in the upper stories and serving them passes very quickly beyond the remunerative point. The writer, having studied the problem carefully, is of the opinion that the economical limit is at sixteen stories, and that as soon as any experience has been gained, this will be abundantly demonstrated.

The author limits the area under consideration to that portion of New York wherein the greater portion of the area has a subsoil composed of a fine micaceous sand. On this the writer has repeatedly founded buildings in which the actual weights ranged from $2\frac{1}{2}$ to $3\frac{1}{2}$ tons per square foot, with a settlement of from $\frac{1}{4}$ to $\frac{1}{2}$ in. The area of the lot, if properly utilized, is therefore more than adequate to carry the superimposed load of a 16-story building, which may be assumed as being 75 lbs. per square foot dead load for floors and framing, 25 lbs. per square foot constant live load, or for a 16-story building a little over $\frac{1}{2}$ ton per square foot. If the walls are averaged at 220 lbs. per square foot 200 ft. high, there would be 22 tons per lineal foot of wall in addition, or about 7 ft. of extra width following around the wall lines. With such a construction it is possible to erect a building, and, at an expense of about $2 a day during erection, to

support the walls of adjoining buildings and preserve them absolutely against settlement, by wedging up as the new footings go down; this was actually done in the case of one building erected under the writer's direction. Mr. Hill.

When sinking pneumatic caissons, the writer has observed that the adjoining buildings were very seriously injured. In the case of the Consolidated Exchange, there were new cracks of about ½ in. caused by this alone, in spite of the fact that the wall is said to be supported on piles.

In regard to spreading the load over the soil, the writer has made comparative calculations of the relative costs of using the Chicago crib method and the method advocated by him in an article in the *American Architect*,* and found the latter much more economical of metal and money, beside affording a very desirable safeguard against injurious effects of undermining of adjoining foundations.

FOSTER CROWELL, M. Am. Soc. C. E.—Certain points brought out in the paper deserve to be emphasized as matters calling for the earnest attention of civil engineers, not only in New York City, but in all other places. First among these from the professional point of view comes the suggestion of the economical necessity of employing expert civil engineers in order to obtain the best results; the description of the contrary methods now in vogue is accurate and suggestive; the condition portrayed is lamentable; and, as the author states, it is hard to understand. Secondly comes the assumption that the Society is the proper center for good influences, corrective of the bad condition, to radiate from. That idea should be forcibly promulgated without reserve. Thirdly is the importance of the engineer's studying and understanding the surrounding conditions of a property where foundations are to be placed under his direction, and wherever possible advising the client against the adoption of plans that will be the cause of ultimate injury to neighboring property, constituting a claim in equity, possibly, against him. Mr. Crowell.

The author's grave suggestions of the evils of overloading a stratum that rests on softer material, causing lateral displacement or squeezing out under the pressure, and consequent injury to other buildings even at a considerable distance, are not overdrawn. The writer knows of cases in point, and especially of one in which all the buildings on the opposite side of a street for a considerable distance were set in motion and some of them wrecked by such overloading.

The conditions at present prevailing in New York are peculiar and to some extent limit the choice of methods; at the same time the experience is valuable to all. The instance cited where the adoption of a pile foundation was impracticable because the entire building space was insufficient to provide room for the number of piles required under

* Vol. XLII, p. 6.

Mr. Crowell. the building law is suggestive in connection with the remarks of the author in regard to the mistake of assuming the sustaining power of a pile foundation to be in all cases the sum of the safe loads on the individual piles. In the writer's paper on "Uniform Practice in Pile Driving,"* this question of overloading a stratum by driving piles too thickly is discussed, as are also the importance and the method of adjusting the unit support in a foundation to the requirements of a building so as to obtain uniform loading, and the further consideration of providing for the effects of vibrations, of machinery, wind, etc., to which the author refers.

Every foundation forms a special study and it is not exaggerating to say that in many cases it is the most important feature in the entire structure, calling for the very best of engineering talent for examination and advice. The amount of money that owners could have saved in known instances by proper methods, as against the unconsidered means adopted, has been very great, and the same rash waste goes on in numerous cases still, because the owner is not aware of the pecuniary value of the right kind of engineering advice, in addition to the safety and security afforded.

A great mistake often made is to adopt a foundation, based on experience of others elsewhere, before the site is examined to ascertain its suitability. A thorough exploration and examination by a fully competent consulting engineer should precede the architectural plans just as certainly as the search of title is a precedent of purchase, and with the same end in view, viz., to guard the owner against injury.

It would be a desirable measure for the Building Department to collect systematically and plot data from every building excavation and boring, of the geologic, topographic and hygrometric conditions of the strata encountered, so that in course of time there would be built up a complete underground map of the city, for the use of all. Examinations disclosing suitable founding strata are as important as those developing the contrary.

Mr. Thomson. T. KENNARD THOMSON, M. Am. Soc. C. E.—As the author points out if the foundations of a building are put more than 10 ft. below the curb, the owner is responsible for the safety of the adjacent walls, even if they are badly constructed or on entirely inadequate bearings. Sooner or later the owner of some of these insecure buildings will find that his confidence has been misplaced, for the construction of the foundations for a new building, two or three lots away, will draw the water and sand from under the over-loaded foundations, when a bad collapse will be certain, and even the present building laws will not help him.

Would not some such clause as the following be just to all parties:

The owner of any building over, say, seven stories high, the foundations of which are not carried to rock by means of piles or caissons,

* See *Transactions*, Vol. XXVII, p. 99.

must take measures to render his own building safe whenever excava- Mr. Thomson.
tions, etc., are carried on in adjacent or near-by lots.

Beside the objections of decay, etc., raised by the author against pile foundations in the lower New York quicksands, there is a great difficulty in making sure that the piles are driven to rock, for even a good engineer will often have his doubts on this matter, to say nothing of a contractor cutting off the piles too soon when not watched.

There is at least one modern high building in lower New York on a concrete foundation which is so heavily over-loaded that no reliable contractor would care to put in the foundations for buildings on the adjacent lots. The author is quite right in saying that it is true economy to go to rock with a pneumatic caisson for high buildings in a case like this, for no reliance can be placed on a rock foundation unless it can be inspected personally.

The writer thinks that the author is wrong in advocating a force account, for all contractors have not his honesty and ability, nor can even he be sure that his men will always be as honest and capable as himself. The following figures give the cost of some work done under a force account contract:

Material in coffer-dams	$22 667
Concrete	9 172
Plant	7 579
Extra work	88 737
Total	$128 155

On the other hand, the writer has known cases where the contractors paid out from 20 to 40% more than they received, which better management might have saved.

The New York building laws allow at present 20 tons on a timber pile not less than 5 ins. thick, resisting power not stated; 15 tons on solid rock, and 10.8 tons on concrete. As the author states, the load on the piles would be all right if the piles were big enough and long enough, but even poor rock or concrete ought to be good for as much.

The writer recently crushed four 6-in. cubes of concrete nine months old. All were made of one part of Portland cement, two parts of clean sand and four parts of trap rock passing a 1¼-in. ring. The first was loaded over its entire surface, and when the load reached 39 000 lbs. the sides cracked off, leaving a block of concrete 4 ins. square by 6 ins. high, which finally collapsed at 104 800 lbs. or 2 910 lbs. per square inch. The second, third and fourth had the load concentrated on a 4-in. block or 16 sq. ins. The second broke at 69 640 lbs. or 4 350 lbs. per square inch; the third broke at 84 300 lbs. or 5 270 lbs. per square inch, and the fourth broke at 87 590 lbs. or 5 470 lbs. per square inch. The first two were of a well-known European Portland cement, and the last two of an equally well-known American Portland.

Mr. Thomson. These cubes were made by the writer while employed as first assistant engineer by Messrs. Jacobs and Davies, chief engineers of the New York and Long Island Construction Company and Bridge, and through their courtesy he was allowed to make the test.

Mr. Harris. R. L. HARRIS, M. Am. Soc. C. E.—When the author's company built the foundation for the Manhattan Building in New York City, the first use of pneumatic caissons for this purpose, the work marked a long step forward and solved many interesting questions to the great advancement of securing foundations for heavy buildings, as also in other directions.

The author states:

"In one case in lower New York where a very massive and well-built structure resting upon gravel and sand cracked after it had been in use a considerable time, the only new condition introduced to which it seemed possible to attribute the settlement manifested was pumping clear water from a nearby driven well. It seemed reasonable to assume that the water flowing through the sand made possible a slight readjustment of the particles which settled into closer union under the vibration of the machinery in the building."

Another reason may be given, which has been little considered. Water occupies space in the ground and is a supporting element practically incompressible; when excavations are made below the ground water level, as for tunnels, deep cuts, sewers, etc., the ground frequently cracks and opens some distance away, in cases over 100 ft., endangering structures. The previous level of the ground-water has been lowered by the draining and pumping, and this evenly distributed supporting medium has been withdrawn and its bulk displaced, except as elastic air may fill the voids. A notable instance of this on a large scale occurred recently at New Orleans. Care, therefore, should be taken in sinking foundations below those of adjoining buildings that much of the water from their supporting ground be not abstracted.

The author also speaks of the dangerous effect of lowering the level of ground-water in the case of pile foundations; this is sometimes dangerous when the adjoining buildings are built directly on sand or gravel.

In regard to the hydraulic method of sinking foundation caissons for the Johnston Building in New York, it should be remembered that this is the first prominent example of such work for heavy building foundations in the vicinity. Caissons sunk by water have been invented within the past two years from which the possible objections stated are eliminated.

Mr. Hunt. RANDELL HUNT, M. Am. Soc. C. E.—If the foundation of a heavy building is regarded as an engineering problem, there should seldom be any error in its general design, for an independent investigation would be made of each site and the correct application of engineering principles would determine the character of construction necessary.

Mr. Hunt.

Hard and fast methods will not apply to foundation practice, whether for a building or a bridge, and the situation must always be studied with regard to the character of the soil and its liability to change in the future. Serious errors in overloading soils have been made in the foundations of many large structures where they have been founded directly upon wet loam and clay. An investigation of a large number of failures of foundations throughout the world has resulted in this conclusion, and has shown that this bad practice is still carried on in certain parts of this country. Such soils have not the supporting strength usually ascribed to them.

From this fact it should not be inferred that a heavy building cannot be placed directly upon such soils, but simply that the pressures must be reduced considerably below the apparent strength of the soil when first tested and investigated. Although a stratum of more or less firm earth often overlies a softer, watery material, yet the pressure transmitted to the latter may be, and often is, beyond the amount which it can carry safely. In the writer's opinion this is without doubt the chief cause of the settlement of many Chicago buildings, viz., the compression of the softer underlying soil, although the load upon the top stratum might be well within its own supporting power if it were of greater depth.

There have been comparatively few failures of foundations placed upon confined sand. If there is every reason to believe that no extraneous conditions are likely to arise, such as deep excavations in the neighborhood or the flooding of the site with water, then it is seldom that a building is constructed, the foundation of which can not be designed within such limits as to give perfectly safe pressures upon the sand. When such modifying conditions are likely to arise, however, and it is the duty of every engineer to investigate these, then recourse must be had to other methods, but whether the end must be achieved by open cylinders, pneumatic caissons, or piles, appears to be a question more or less undeterminate in advance of a thorough investigation of the physical characteristics and permanence of the foundation site.